Wellbore Integrity & Drilling Technology

Introduction

Well integrity and drilling technology is critical across all DOE programs focused on subsurface extraction of resources, energy storage, disposition of energy waste streams, and the remediation of sites contaminated from past endeavors. This need extends across a wide range of geologic environments from deep, high-temperature applications in fractured rock to unlithified sediments in the vadose zone and time-scales from weeks to eons. Despite industry interest and investment in well integrity and drilling technology, better solutions are needed. Key research needs are:

- Novel Materials For Well Completion
- Real-Time In Situ Data Acquisition and Transmission
- Diagnostics Tools for Well Integrity and Remediation Tools to Correct Deficient Well Integrity
- Quantification of the Behavior of Seal Materials and the Causes and Consequences of Failure
- Advanced Drilling and Completion Tools
- Technology for Effective Well Abandonment and Analysis of Legacy Issues

Knowledge Gaps and Proposed Research

Materials

Development of novel and enhanced engineered materials is crucial to creating more robust and reliable wellbore systems. Critical materials research problems include enhanced casing, cement, centralizers, lost circulation mitigation materials, and drilling fluids. In current practice, cemented steel casing is a passive component of the well system. There is potential to make the casing system an active probe of the subsurface environment where the casing system integrates sensors to monitor a suite of parameters (e.g., hydraulic containment, casing stress, corrosion, …). Additionally, there is a need to develop casing/cementing systems that are tailored to the target application and subsurface system using materials and processes appropriate for the application. While expandable casing has seen increasing use in the O&G sector, there exists the need to continue advancement of "cementless" casing systems to increase wellbore performance and to reduce costs. New casing systems that provide superior performance at costs appropriate for the application are needed, including next-generation casing/cement systems that self-heal in response to mechanical or chemical damage and are more durable in aggressive chemical environments and at high temperatures. Casing centralization methods that do not impede installation but enhance cementing processes should be developed. Bonding of cement to casing and rock can be enhanced through improved drilling technologies (e.g., drilling "gun barrel" holes) or new methods of annulus cleaning or chemical pre-treatment of the system.

Real-Time In Situ Data Acquisition and Transmission

While systems for real-time logging and directional control exist for drilling operations (at moderate temperatures), there is a paucity of "health-of-system" downhole monitoring options available today following the construction phase of a well. These sensing systems are needed across a wide-spectrum of applications and across time-frames not considered today. For example, the ability to monitor and transmit parameters such as hydraulic containment, casing stress, corrosion, rock/cement/casing bond, and other system performance parameters are not available but are of great interest in all borehole applications.

Diagnostics and Remediation Tools and Techniques

There will always be the need to remediate wells where the integrity of the well has been compromised. Robust logging systems, fit for the purpose of the well, are needed to diagnose the precise location and character of the problem. These tools could utilize specific physical signals or could involve the development of analytical techniques based on more general tools that allows reliable diagnostics of the integrity of the wellbore. These diagnostics would facilitate accurate targeting of remediation efforts and the selection of the appropriate remediation methodology. Today's remediation tools rely on placing patches over the unintended breaches in the casing system or purposefully breaching the casing/cement sheath and injecting materials into the offending region. We need remediation tools that selectively perforate and inject materials tailored for the particular geologic region or tools that are nonintrusive and perhaps activate a built-in healing capacity of the well system.

Quantification of Seal Materials and Failure

Previous work has focused on the properties of the individual materials comprising the wellbore seal: casing, cement and rock. However, wellbore integrity involves the performance of the coupled casing+cement+rock system. Failure occurs when the coupled system is unable to accommodate the thermal, chemical and geomechanical stresses imposed by drilling operations and the geological environment. For example, little is known of corrosion rates and impacts when aggressive (e.g., CO_2- or H_2S-bearing) fluids attack the composite steel-cement system. Similarly, we do not yet understand whether geomechanical stresses are aggravated or mitigated by the contrasting mechanical properties of steel, cement and rock; or how to properly modify designs to mitigate geomechanical stresses. Research is needed to study coupled processes experimentally, computationally, and in the field to quantify the behavior of seal materials, the mechanisms of seal failure, and the consequences of failure in terms of fluid flow, loss of well stability, and damage to the environment.

Advanced Drilling and Completion Tools

Drilling and completion technologies are well advanced in O&G and other sectors but not wholly applicable to the various needs of DOE programs. While a thorough examination of available technologies must be compared against program needs there are significant opportunities to improve performance and costs of program-related drilling and completion technologies. DOE programs require a wide range of well types and adapting, modifying or developing targeted drilling technologies and processes for specific applications is needed for the range of well types envisioned (e.g., wells for seismic monitoring of deep borehole disposal of nuclear waste). Well completions that incorporate "smart" technologies (e.g., zonal isolation, valves, sensors) for applications ranging from geothermal development to environmental restoration are required. Next generation logging-while-drilling and measurement-while-drilling systems are needed: examples include providing enhanced seismic and electromagnetic imaging and geosteering relevant to the application (e.g., salinity, temperature,…). Concepts regarding the development of multilateral systems to provide greater subsurface access with minimal surface infrastructure should be examined. More efficient hole advancement methods, fit for purpose drilling fluids, and advancements in downhole telemetry systems will benefit all well construction applications.

Well Abandonment Analysis

With every year, the US inventory of plugged and abandoned (P&A) wells grows. While regulations exist to ensure that P&A wells will not impact the environment or interfere with the redevelopment of a resource, it is clear that many wells are improperly abandoned and represent a long-term threat. A detailed study of the efficacy of past and present abandonment practices and long-term outcomes is badly needed. We need to quantify the potential risks from improperly abandoned wells and develop effective strategies for mitigating potential damage. Understanding the state of technology will enable the development of more reliable abandonment processes, improved abandonment materials, and reliable performance assessment tools for a broad set of applications applicable to the DOE mission.